The Society for engineering in agricultural, food, and biological systems

Paper Number: AA03-007
An ASAE Meeting Presentation

Field Swath and Drift Analyses Techniques

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Written for presentation at the
2003 ASAE/NAAA Technical Session
Sponsored by ASAE Technical Committee PM23/6/2 and
National Agricultural Aviation Association
37th Annual National Agricultural Aviation Association Convention
Silver Legacy Hotel and Casino, Reno, NV
December 8, 2003

Abstract. Researchers use a variety of techniques for measuring spray droplet deposition and movement. Techniques range from passive samplers such as water sensitive paper or mylar cards to active samplers such as rotary rods and high-volume air samplers. In most field studies, researchers use one or two different types of samplers but rarely more than three. In this collaborative study, three types of horizontal collectors were placed in the field at the same time. The objective was to investigate correlations in deposition and drift data that these different sampling devices collected. Five sets of ASAE reference nozzles from ASAE Standard S572 AUG99, which produce droplets from Very Fine to Extremely Course, were fitted to a Cessna Ag Husky.

At 0-25 m (0 – 82 ft) from the downwind edge of the spray swath, there were highly significant correlations between the three samplers for the two nozzles that produced the largest droplet spectra. As the droplet spectra became smaller, a greater portion of the spray volume was subject to entrainment in the air and resulted in inconsistent and mostly non-significant correlations between the samplers for the three sets of nozzles that generated the smaller droplet spectra. There was a highly significant correlation for the water-sensitive paper and mylar card samplers that were placed under the aircraft (i.e., in-swath). The droplet spectra data from the water-sensitive paper samplers placed in-swath separated out along the droplet classification lines in ASAE Standard S572. The monofilament line samplers at 50 m (164 ft) showed that nozzles that produced smaller droplet spectra generate more airborne spray material downwind than nozzles with larger droplet spectra.

Keywords. Aerial application, water-sensitive cards, MGO slides, deposition

Field Swath and Drift Analyses Techniques

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Introduction

The British Crop Protection Council (BCPC) devised a nozzle classification system that placed nozzles into five classes (very fine, fine, medium, coarse, and very coarse) based on the characteristics of the droplet spectrum (Doble et al., 1985; Southcombe et al., 1997). Nozzles can change from one classification to another when spray pressure, orientation and/or airspeed are changed. The BCPC classification scheme was modified for the United States (Womac et al., 1999) through ASAE Standard S572 AUG99 (ASAE Standards, 2000). The U.S. classification scheme uses droplet spectra to place a nozzle into one of six categories (very fine, fine, medium, coarse, very coarse, or extremely coarse) as defined by a set of five reference nozzles.

Many crop protection and production materials are now requiring specific droplet sizes for application, such as "apply as a MEDIUM spray." Therefore, it is important for researchers and applicators to understand droplet size spectra. The most common term used to describe agricultural spray droplet size spectra is volume median diameter ($D_{V0.5}$). $D_{V0.5}$ is the droplet diameter (µm) where 50% of the spray volume or mass is contained in droplets smaller than this value. Two additional droplet size parameters that are commonly used to describe more of the distribution than the median alone are the $D_{V0.1}$ and $D_{V0.9}$. These describe the proportion of the spray volume (10% and 90%, respectively) contained in droplets of the specified size or less.

Objective

- To concurrently measure spray deposition and droplet spectrum from ASAE Standard reference nozzles with commonly-used measurement systems;
- To evaluate the correlation between horizontal deposition collected with different sampling systems, specifically, water-sensitive paper, mylar cards, and magnesium oxide slides.

Materials and Methods

Treatments

The spray solution was water, Triton X-100 at 0.1% v/v, and Caracid Brilliant Flavine FFN fluorescent dye at 25 g/ha. The fluorescent dye was used as a tracer to measure the deposition and downwind movement of the spray during the tests. The treatments selected for this study were the reference nozzles that delineate droplet spectra classifications for the American Society of Agricultural Engineers (ASAE) Standard S572 AUG 99: Spray Nozzle Classification by Droplet Spectra. This standard "defines droplet spectrum categories for the classification of

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spray nozzles." (ASAE, 2000). The reference nozzles were placed on a Cessna AgHusky aircraft with the following operational parameters: speed - 160 km/hr (100 mph), spray release height - 2 m (6 ft), swath width – 14 m (45 ft), application rate – 28 L/ha (3 gpa). The operating pressures and number of nozzles (table 1) were adjusted to keep the application rate constant for all treatments. All nozzles were orientated 0º (straight back). Each treatment was replicated four times in this study. The weather conditions were fairly consistent over all the treatments (table 2).

Table 1. Nozzles and operational parameters used for each treatment

Reference Nozzle Classification	Nozzle	$D_{V0.5}$[a] (µm)	Pressure (kPa (psi))	Number of Nozzles on Boom	Treatment
VF/F	01F110	160	450 (65)	40	5
F/M	03F110	283	250 (36)	30	4
M/C	09F110	316	330 (48)	18	3
C/VC	8008	420	275 (40)	28	1
VC/XC	6510	462	241 (35)	24	2

[a] – Volume median diameter (µm) for a water only solution. Data measured using a Malvern 2600 in a 160 km/h (100 mph) airstream.

Table 2. Average weather conditions over the four replications of each treatment.

Treatment	Temperature (ºC (ºF))	Relative Humidity (%)	Wind Speed (m/s (mph))
1	24.4 (75.9)	59.9	4.4 (9.8)
2	24.6 (76.3)	59.2	4.6 (10.3)
3	23.6 (74.5)	84.2	3.3 (7.4)
4	22.4 (72.3)	88.6	3.9 (8.7)
5	22.7 (72.9)	86.1	3.6 (8.1)

Study Layout and Treatment Procedures

The in-swath deposition and downwind movement (i.e., drift) of applied material released from the aircraft were measured by flying the aircraft perpendicular to the prevailing wind. Sampling stations were placed parallel to the wind (fig. 1). There were 12 samples at 1.5 m intervals within the swath (i.e., under the aircraft) and 11 samples at 5 m intervals from the downwind edge of the swath. At each sampling location, samplers were placed side-by-side on a square board placed on level ground. The three samplers used in this study are described in the following section. All applications were made in a pasture with 5 cm (2 in) grass stubble.

The aircraft made two passes over the described course for each of the four replications of each treatment always turning on the spray 300 m before the sampling lines and turning off the spray 300 m after the sampling lines. One pass was made with the left wing on the downwind side and one pass was made with the right wing on the downwind side. Both passes were made over the same swath and along the flightline shown in Figure 1. After each replication, sufficient time was allowed for the spray material to move downwind and the cards and papers to dry (approximately 5 minutes).

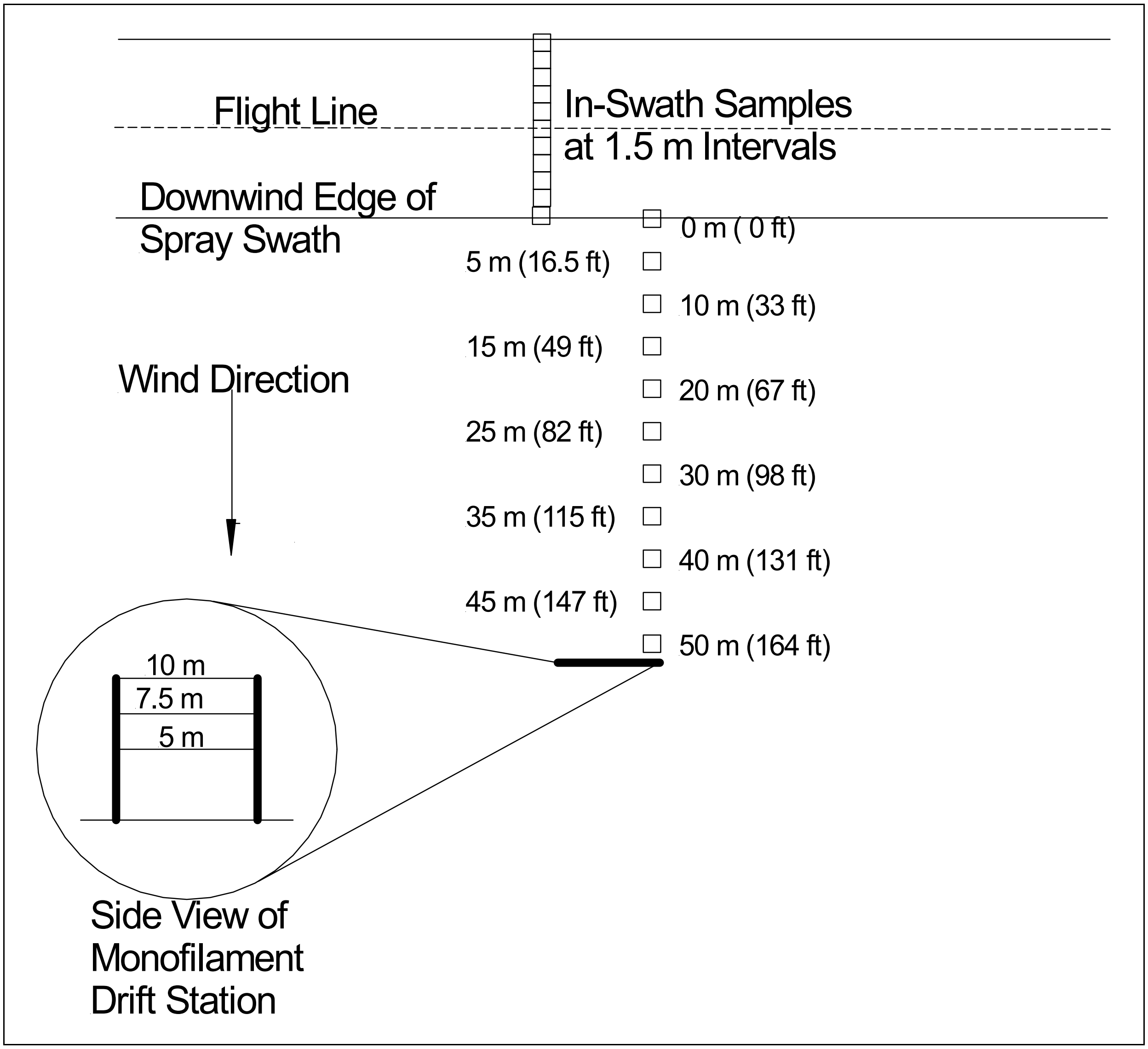

Figure 1. Test site layout showing flight line (dashed line) and sample locations (boxes).

Samplers

Water-sensitive papers: Water-sensitive papers (WSP) (Novartis Corp., Basel, Switzerland) were one of the samplers used in the analyses of the application treatments. The 2.5 cm X 7.5 cm WSP was placed at both the in-swath and downwind sampling locations. After each treatment replication, the WSP were allowed to dry and placed in labeled negative film holders. WSP were analyzed on imaging equipment system operated by the Aerial Application Technology Group of USDA-ARS in College Station, TX, USA. The system is composed of a CCD camera and IMAQ Vision Builder 5 software. The camera has a resolution of 15.5 µm/pixel. The system is operated to capture droplet images from two, randomly-selected, 0.76

cm² areas on each card and pool the two samples into one data set for each card. The spread factor equation used by the imaging system to convert droplet stains on the WSP to actual droplet size, which caused the stain, was:

Actual droplet diameter = (0.53549306* Stain diameter) - (0.000084839 * Stain diameter^ 2).

It should be noted that this equation is only valid for the spray solution used in this study.

Mylar Cards: At each sampling location, mylar cards (100 cm²) were secured horizontally on a metal plate that was placed next to the other samplers. After each replication and allowing sufficient time for the spray material to move downwind, each mylar card was placed in a labeled plastic bag, stored in an ice chest, and transported to the laboratory for quantification. The cards were exposed to the sunlight for less than 15 min following an application; therefore, no appreciable degradation of the fluorescent dye would be expected. Forty or twenty ml of ethanol was pipetted into each bag, the bags were agitated, and 6 ml of the effluent was poured into a cuvette. The cuvettes were then placed into a spectrofluorophotometer (Shimadzu, Model RF5000U, Kyoto, Japan) with an excitation wavelength of 453 nm and an emission at 488 nm. The fluorometric readings were converted to µg of dye/cm². The minimum detection level for the dye and sampling technique was 0.00007 µg/cm².

MGO Slides: Glass slides (2.5 cm X 7.5 cm (1 in X 3 in)) were uniformly coated with magnesium oxide. The slides were placed next to the other samplers at the sampling locations downwind from the edge of the spray swath (fig. 1). Following each spray run, slides were collected, stored in standard slide boxes and read during the following several weeks. At least 100 drops or 10 sweeps of each slide were measured and counted using a traversing method across each slide. A standard American Optical Model 100 binocular microscope was used to conduct all counts and measurements. The MGO slides were placed at the 13 locations downwind from the edge of the swath. The ratio of true drop size to impression size on the MGO slides is constant at 0.86 for droplets larger than 20 µm for any liquid (May 1950). For droplets smaller than 10 µm, the MgO method is of little value (May 1950).

Drift Measurement by Monofilament Strings

At 50 m (186 ft) from the downwind edge of the spray swath, two vertical towers were positioned 10 m (33 ft) apart. Monofilament line was suspended between these towers at 5, 7.5, and 10 m (16.5, 24.9, and 33 ft, respectively) (fig. 1). The lines were parallel with the flightline and provided a measure of the airborne component of the spray. After each replication, the towers were lowered and the monofilament line was collected on reels that were built for this study. These reels allowed the line to be collected without touching the ground. Each reel was placed in a labeled plastic bag, stored in an ice chest, and transported to the laboratory for quantification. After pipetting 40 ml of ethanol into each bag, care was taken to thoroughly wash the monofilament line and the spool in the bag to allow all of the dye to be dissolved in the solution. Sample analyses and quantifications were performed as described for the mylar card samples.

Statistical Analyses

All correlation analyses were performed using the Proc CORR procedures in SAS (SAS Institute, 2001). This procedure computed the Pearson's Correlation Coefficient between two samplers. Treatment means at the three heights of the monofilament line samples were separated by Duncan's Multiple Range Test (α = 0.05) in the PROC GLM procedure in SAS.

Results and Discussion

Samples 0 – 25 m (0 – 82 ft) from Downwind Edge of Swath

All three samplers were located at downwind sample locations from 0-50 m (fig. 1). The WSP samples detected essentially no droplet deposits beyond the 25 – 35 m (82 – 115 ft) sample locations. Therefore, the correlations between the different samplers were analyzed for the 0 – 25 m sample locations. There was significant correlation between each combination of samplers for Treatments 1 and 2 (table 3). These two treatments contained the largest droplets, which tend to produce a more predictable and less variable deposition pattern. As the droplet spectra become smaller, a greater portion of the spray volume is subject to entrainment in the air and subsequently, deposition is more variable. This was evident in the inconsistent and mostly non-significant correlations between the samplers for Treatments 3-5 (table 3).

Table 3. Correlation matrix for the deposition measured by the three samplers by treatment for samples collected from 0 – 25 m downwind of the swath edge.

	Treatment 1	Treatment 2	Treatment 3	Treatment 4	Treatment 5
Samplers	Correlation[a] (Prob > |r|)[b]	Correlation (Prob > |r|)	Correlation (Prob > |r|)	Correlation (Prob > |r|)	Correlation (Prob > |r|)
Mylar – MGO	0.5461 (0.0058)	0.6079 (0.0016)	-0.0584 (0.8570)	0.4594 (0.1330)	0.6365 (0.0261)
Mylar – WSP	0.9104 (0.0001)	0.9409 (0.0001)	0.6450 (0.0235)	0.2292 (0.4737)	0.2890 (0.3623)
MGO – WSP	0.4061 (0.0490)	0.6040 (0.0018)	0.3605 (0.2497)	0.5351 (0.0730)	0.6195 (0.0317)

[a] Pearson correlation coefficients, n = 24.
[b] Probabilities less than 0.05 are statistically significant.

The droplet spectra measured by the different samplers showed that the droplet size was largest for Treatments 1 and 2. For the WSP, the mean $D_{V0.5}$ were 235, 234, 161, 158, and 102 µm for Treatments 1-5, respectively. For the MGO slides, the mean $D_{V0.5}$ were 346, 345, 118, 156, and 110 µm for Treatments 1-5, respectively. The $D_{V0.1}$, $D_{V0.5}$, and $D_{V0.9}$ values by distance from the downwind edge of the swath are shown in Figure 2. The droplet size parameters generally decreased as distance downwind from the spray swath increased. This effect could be caused by the larger droplets from the spray spectrum settling out of the spray cloud as it moved downwind.

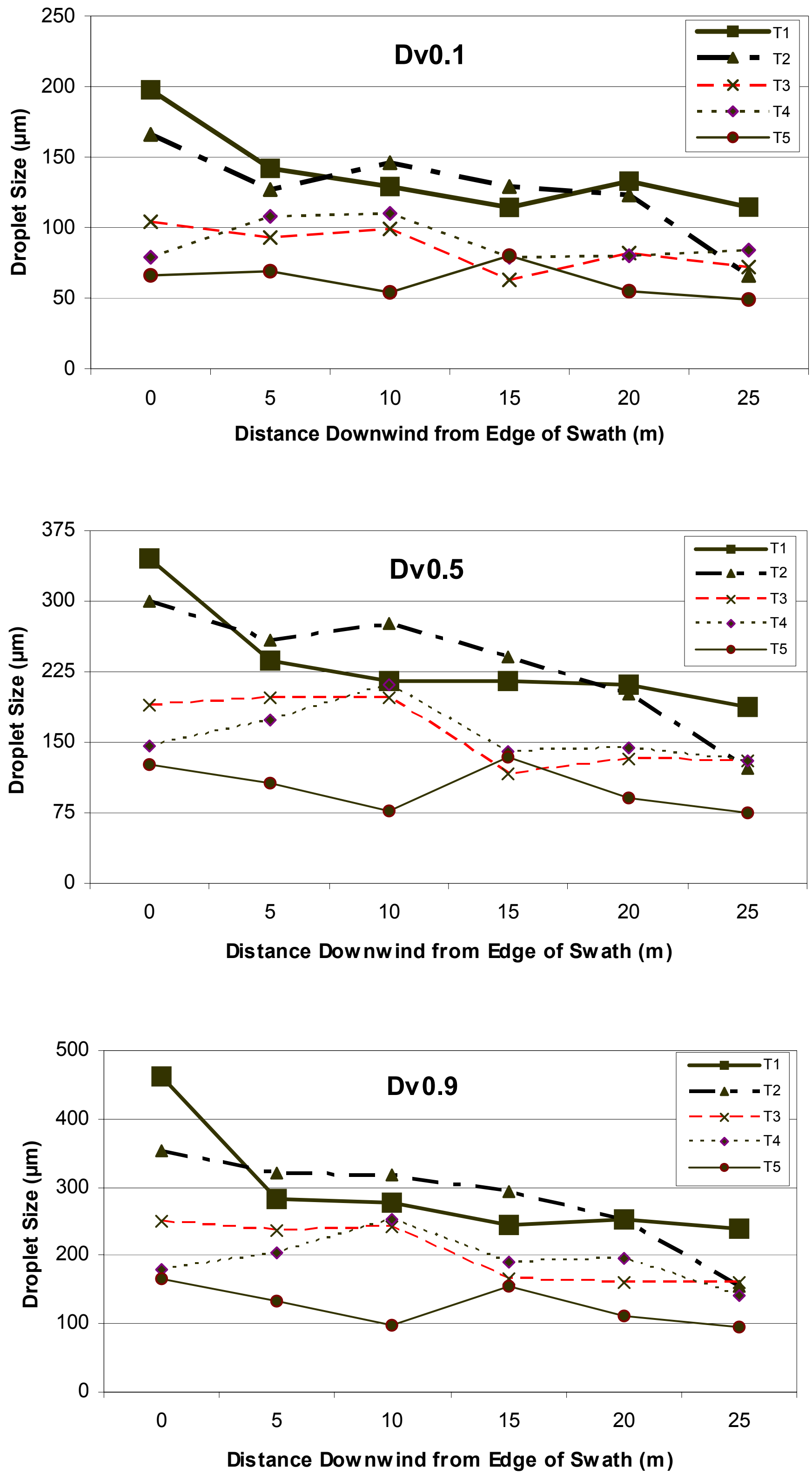

Figure 2. Droplet spectra by treatment from water-sensitive papers for downwind distances.

In-swath Deposition and Droplet Spectra for ASAE Reference Nozzles

Mylar cards and WSP were placed side-by-side on horizontal boards under the aircraft at 1.5 m (5 ft) intervals with the centerline of the aircraft at 8.25 m (22.5 ft). The correlation coefficients between the two sampling methods were 0.764, 0.686, 0.613, 0.877, and 0.720 for Treatments 1-5, respectively, and all were highly significant ($p<0.0001$, $n=48$). These correlations were generally higher than those presented in table 3 because the samples were directly under the aircraft. With these results, researchers can be confident that similar deposition results will be measured whether one is using WSP or mylar cards when both are laid flat on the ground.

There are no published reports for the droplet spectra for the ASAE reference nozzles from horizontal deposition from an aerial application. The droplet spectra data ($D_{V0.1}$, $D_{V0.5}$, and $D_{V0.9}$) from WSP placed directly under the aircraft is presented in Figure 3. The different treatments separated out by droplet size, as one would expect. The data also suggest a 6 m (20 ft) or 40% swath displacement caused by the perpendicular winds. These results support the common practice used by aerial applicators of offsetting the spray swath from ½ to 1 full swath upwind while spraying in crosswinds.

Monofilament Line Samplers at 50 m (186 ft)

Deposition on the monofilament lines decreased as sampling height increased for each Treatment except the 7.5 and 10 m measurements for Treatment 5 (fig 4). Treatments 1 and 2 had the lowest deposits at each of the heights although these deposits were not always significantly different for the other treatments. Treatments 3, 4, and 5 had the highest deposits on the monofilament samples, which was expected since these Treatments produce the smallest and most driftable droplet spectra.

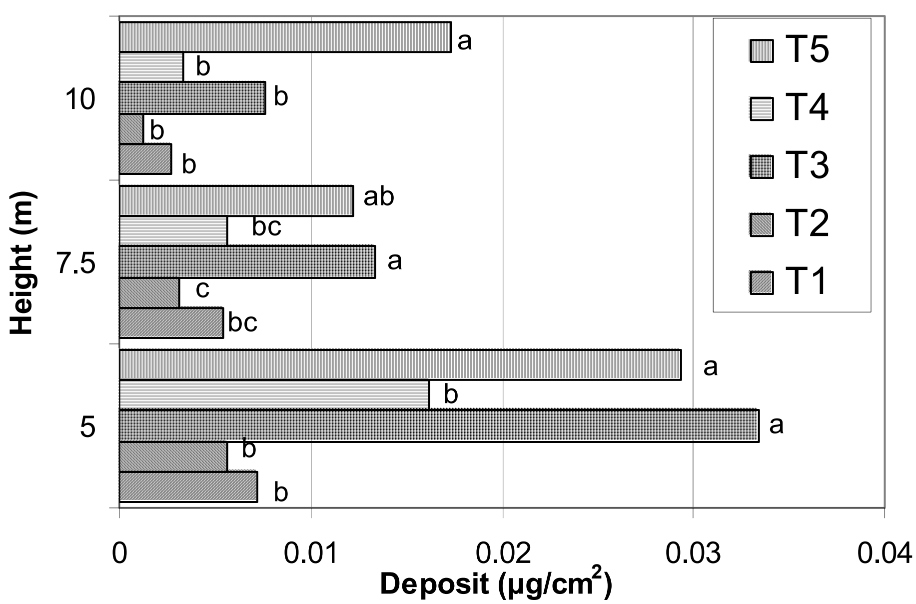

Figure 4. Deposition by treatment on monofilament lines placed 50 m (82 ft) downwind from the swath edge at three heights. Treatment deposits at each height followed by the same letter are not significantly different ($p < 0.05$).

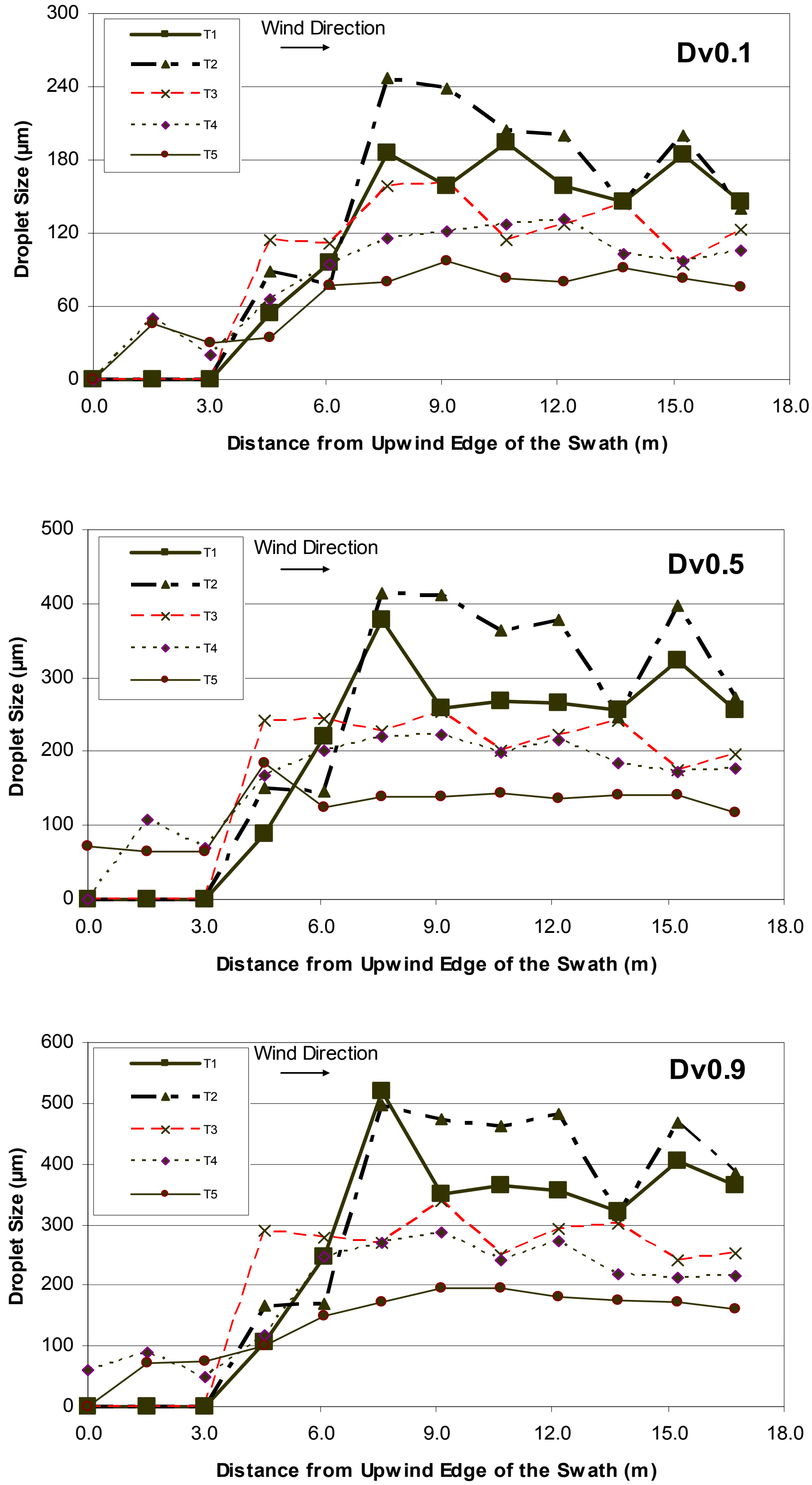

Figure 3. In-swath droplet spectra as measured on horizontal water-sensitive cards. The centerline of flight was at 6.9 m (22.5 ft).

Summary

Five sets of ASAE Reference nozzles as specified by ASAE Standard S572 AUG99 were placed on a Cessna AgHusky aircraft to evaluate the horizontal deposition and droplet spectra from the different nozzles. Three different samplers (water-sensitive paper (WSP), mylar cards, and magnesium oxide (MGO) slides) were placed side-by-side at various in-swath and downwind locations to determine the correlation of the deposition results from the three samplers. Downwind movement of the airborne spray droplets from the five different nozzle sets was measured at 50 m (164 ft) downwind of the spray swath using monofilament lines at three different heights.

At 0-25 m (0 – 82 ft) from the downwind edge of the spray swath, there were highly significant correlations between the three samplers for the two nozzles (Treatments 1 and 2) that produced the largest droplet spectra. As the droplet spectra become smaller, a greater portion of the spray volume is subject to entrainment in the air and resulted in inconsistent and mostly non-significant correlations between the samplers for the three sets of nozzles that generated the smaller droplet spectra (Treatments 3-5). There was a highly significant correlation for the WSP and mylar cards that were placed under the aircraft (i.e. in-swath). The droplet spectra data from the WSP placed in-swath separated out along the droplet classification lines in ASAE Standard S572 AUG99. The monofilament line samplers at 50 m (164 ft) showed that nozzles that produced smaller droplet spectra generate more spray material airborne downwind than nozzles with larger droplet spectra.

Acknowledgements

The authors would like to thank Hal Tom for piloting the aircraft and Phil Jank, Charlie Harris, Steve Harp, Chris Parker, Curtis Hubbard and Bill Bagley for field collection and sample processing.

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